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BOARD OF BUILDING REGULATIONS AND STANDARDS

NOTICE OF MEETING

In accordance with the provisions of G.L. c. 30A § 20, notice is hereby given that a meeting of the ***Energy Advisory Committee of the Board of Building Regulations and Standards*** will be held on:

Friday April 7
10:00 AM

CLEAResult's offices
50 Washington Street, Westborough, MA 01581

Posted on: March 31st at 6:00 PM

It is anticipated that the topics shown below will be discussed at the aforementioned hearing and meeting:

EAC MEETING
AGENDA

Roll Call, by EAC Chair.

Wagdy Anis, Chair (WA)	☐ present	☐ absent	Don Vigneau (DV)	☐ present	☐ absent
Michael Andelman, Vice-chair (MA)	☐ present	☐ absent	Peter Ostroskey (PO), or designee	☐ present	☐ absent
Robert Anderson, or designee	☐ present	☐ absent	Hussein Moussa (HM)	☐ present	☐ absent
Michael Browne (MB)	☐ present	☐ absent	Mark Halverson (MH)	☐ present	☐ absent
Fran Boucher (FB)	☐ present	☐ absent	David Weitz (DW)	☐ present	☐ absent
Ian Finlayson (IF)	☐ present	☐ absent	*open*	☐ present	☐ absent
Isabel Kaubisch (IC)	☐ present	☐ absent			

Agenda:

1. Solar ready requirements RB103 (Comments from homebuilders to delete requirement) EAC comment to support?
2. EV Charging stations: Comment by manufacturers of charging stations and environmental group in support.
3. Strapping in ceilings. Need proposed language to seal and compartmentalize?

4. Clarification of ECB modelling of C406.1 Exception 2 mandatory requirements in ASHRAE 90.1 Chapter 11 or Appendix G
5. Clay brick 4"+ as acceptable air barrier assembly: **C402.5.1.2.2 Assemblies**. Assemblies of materials and components with an average air leakage not greater than 0.04 cfm/ft ^{2} (0.2 L/s · m2) <u>2. Masonry walls constructed of clay or shale masonry units with a nominal width of 4 inches (102 mm) or more.</u> In support of deleting the clay brick assembly, attached is a paper by Lux and Brown that shows that clay brick leaks 8x more than the assembly allowable rate in the code. (0.32 cfm/ft^2 @1.57psf (1.6 L/s*m^2 @ 75 Pa) instead of 0.04 cfm/ft^2 @1.57psf (0.2 1.6 L/s*m^2 @ 75 Pa)) This assembly is not in 90.1. Propose to delete.
6. Revisit the wording of the stretch energy code (appendix 115.AA) to clarify the intent; (referencing the IECC 2015 residential energy chapter instead of IRC 2015 which has not yet been adopted).
7. Clarify when multi-family buildings fall under stretch code criteria, for 4 story multifamily buildings over 100,000 sq ft: the stretch code requires the ERI approach (HERS ratings) for residential dwelling units of 4 stories or less, but also requires ASHRAE 90.1-2013 modeling and energy reductions of 10%
8. Other business.

BUILDING SCIENCE INSIGHT

Air Leakage Control

M.E. Lux and W.C. Brown

Introduction

The 1985 edition of the National Building Code added an important requirement for the proper performance of buildings constructed in Canada, that is, the control of air flow through the building envelope. To quote from the Code:

> "...a *building* assembly...shall be designed to provide an effective barrier to air exfiltration and infiltration,...through
> (a) the materials of the assembly,
> (b) joints in the assembly,
> (c) joints in components of the assembly, and
> (d) junctions with other building elements."

This raises several questions. What is meant by an effective air barrier and why is it necessary? How can we design, build, and confirm the existence of, an effective air barrier? While we are still searching for complete answers to some of these questions, we do have the basic knowledge to answer most of them.

Wind and Air Pressures on the Building Envelope, by U. Ganguli, examines the structural requirements of effective air barrier systems. This paper reviews the present knowledge about effective air barrier systems from the viewpoint of air leakage. It looks at

> (a) why we need an effective air barrier system, and the consequences of an ineffective one;
> (b) what constitutes an effective air barrier system; and
> (c) what test procedures and acceptance criteria are available to test for the effectiveness of an air barrier system.

Consequences of an Ineffective Air Barrier System

The concept of the building envelope as an environmental separator was first promoted by Dr. Neil Hutcheon, former Director of the Division of Building Research, in a talk to the Engineering Institute of Canada in 1953.[1] Dr.Hutcheon listed the principal requirements of the building envelope, so that each could be addressed separately and in conjunction with its counterparts. He noted that building envelops had to be designed to control air flow and the moisture and energy flow associated with it. To quote from his talk:

> The flow of heat, moisture and air in walls have implications not only by themselves, but for all the other considerations listed. Air merits major consideration mainly because of its influence on heat and moisture flow. The overall transmission of heat, air and moisture through a wall can affect the ease with which the desired environmental conditions may be maintained, and so may have a marked influence on cost of operation of a building.

As noted by Dr. Hutcheon, uncontrolled air flow, or air leakage, can have a detrimental effect on the performance of a building. For example, the energy use associated with infiltration may account for more heat loss than is occurring by conduction through the insulation. Infiltration of cold air in space adjacent to the exterior walls, particularly corner offices, may result in a loss of temperature and humidity control, plus other associated problems such as freezing of pipes. Exfiltration of moisture-laden air can cause a number of problems on a wide range of buildings. For example, the build-up of moisture in the building envelope can reduce the service life of materials in the envelope.

These potential problems are not hypothetical; we see them in many of our problem buildings.

A swimming pool, constructed in Eastern Canada more than six years ago (Figure 1), had walls made of concrete block, EPS glued on the exterior, an air space, and a concrete block cladding. The interior was covered with a vapour retardant paint and acoustic insulation over the top half of the wall. No attempt was made to provide for an air barrier system in the wall. Exfiltration of indoor air caused dust marking to appear on the inside of the acoustic insulation, very clearly outlining the concrete block, and spelling of the exterior finish due to moisture accumulation and freeze/thaw cycling.

Figure 1 Dust marking on the acoustic insulation is due to air leaking through this swimming pool wall.

A five-storey building constructed in Western Canada had a make-up water requirement of more than 3000 L a week to maintain a quite modest relative humidity in its computer facility. The quantity of water being used led the building owner to suspect a problem in the building envelope. After an extensive retrofit to increase the tightness of the air barrier system, including elimination of leaks such as the one shown in Figure 2, the make-up water requirement was reduced to 200 L per week. The remaining 2800 L had presumably been carried out of the building by exfiltration. By increasing the tightness of the joints in the air barrier system, the owner drastically reduced his humidification requirement and, more importantly, eliminated a potential condensation problem.

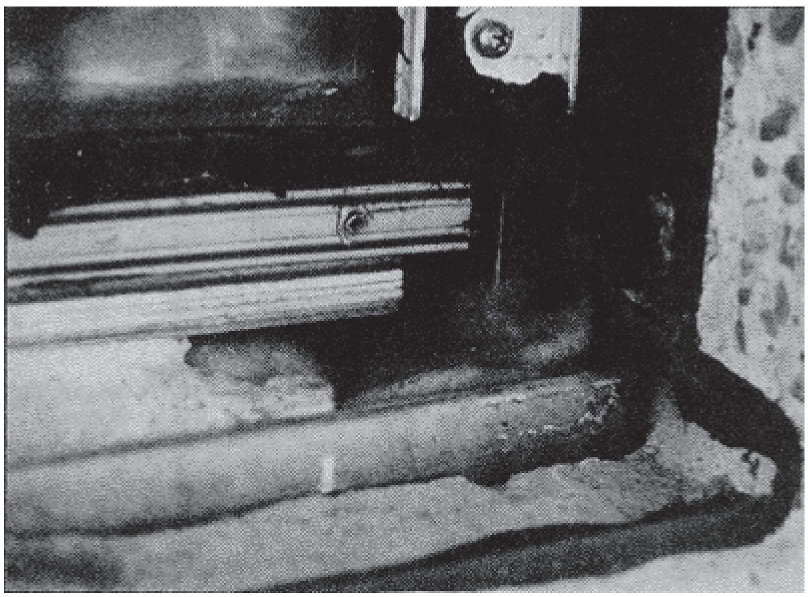


Figure 2 Discontinuity of the air barrier system at the wall/window interface.

The previous two examples illustrate problems in buildings constructed with leaky air barrier systems. *The Air Barrier Defined,* by R.L. Quirouette, illustrates more of the problems that can result from a leaky air barrier system. In *Wind and Air Pressures on the Building Envelope,* U. Ganguli explains the forces that can act on a building, primarily due to wind, but also due to stack and mechanical pressures, and the possibilities for the development of holes and leaks and failures of walls and roofs.

What Constitutes an Effective Air Barrier System?

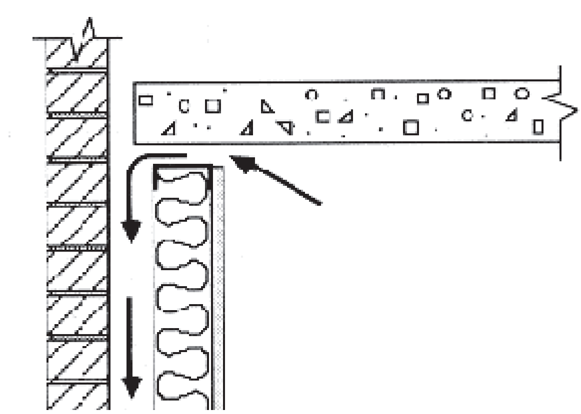
Control of air flow has to be designed into the building envelope right from the conceptual stage. We often refer to the use of an 'air barrier' to perform this function in a wall, but it is most important to note that an air barrier is *not* a single material. We cannot buy an 'air barrier' off the shelf. An air barrier is a *system,* made up of materials, joints, and assemblies. We must consider a line, or plane, of airtightness. This line of airtightness must be continuous, so that in the design stage we can see impermeable materials, held rigidly or rigid in themselves, sealed at any joints, and joined and sealed to other assemblies. We often say that you should be able to take any drawing and trace the line of airtightness around the drawing without lifting your pencil. This must be possible for all drawings, for any cross-section, for each dimension.

Types of Air Flow

To appreciate the complexity of designing an effective air barrier system, it is useful to put air flow into two broad categories. These categories correspond to the types of leaks which can occur in an air barrier system.

The first category of air flow can be described as 'diffuse flow,' that is, air flowing uniformly through a material. This type of flow can be the least obvious because it occurs through materials which are assumed to be impermeable. Diffuse flow through fibrous insulation is an obvious example; flow through a simple uncoated concrete block wall is less obvious.

The second category of air flow can be called 'channel flow,' that is, air flowing through channels and passages in the building envelope. The openings in the inside and outside of the wall may be in close proximity with each other, in which case the air goes straight through the building envelope. This type of channel flow is sometimes referred to as 'orifice flow.' However, with channel flow, we can usually only find the openings in the interior and exterior facades of the building envelope, and cannot easily determine the leakage path between the entrance and exit holes. Infra-red thermography can sometimes be used to follow a leakage path. Channel flow most commonly occurs because of a leak at a joint in the air barrier system. Channel flow can be the biggest cause of moisture problems because when the leakage path is lengthened, the exfiltrating air has time to cool and deposit its moisture as it passes through the building envelope (Figure 3).



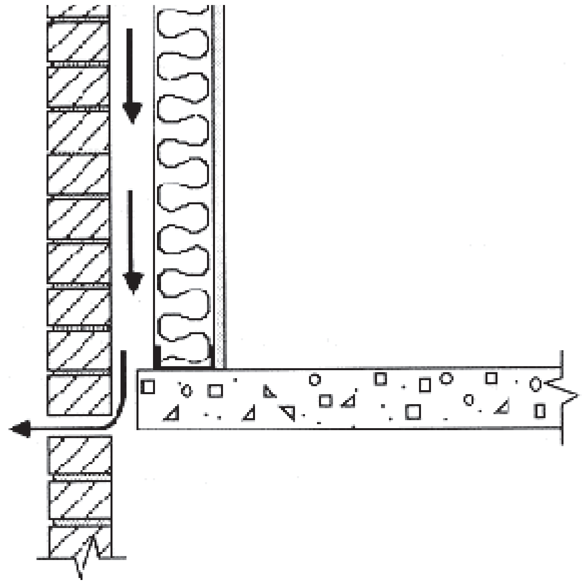


Figure 3 Channel flow through widely separated openings in the interior wall and exterior cladding can lend to cooling of exfiltrating air and condensation within the wall.

Air barrier systems must be built up in stages. These stages can be arranged as in Figure 4, where different materials are brought together at joints to make up assemblies, and assemblies are joined and sealed together to make up the system. For example, the materials can be glass and aluminum, joined together to make up a curtain wall assembly, which then can be joined to precast panels. Each panel can be made up of precast concrete, a reinforced bituminous membrane and a backup infill wall. The airtight joining and sealing of the curtain wall to the precast assemblies and to the roof forms the air barrier system.

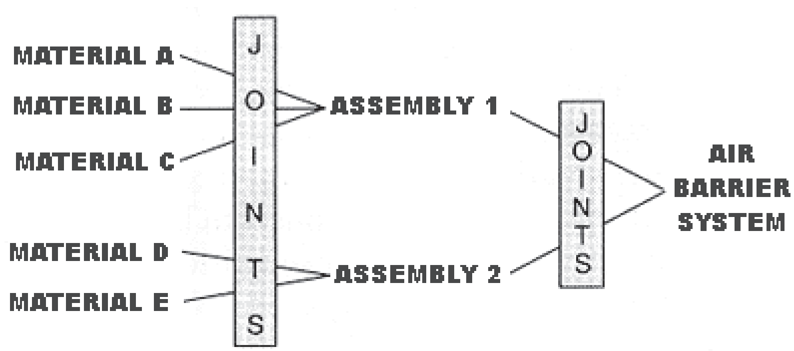


Figure 4 Many elements make up the air barrier system; proper detailing of joints is critical to its effectiveness.

The primary elements within an air barrier system are the materials, which must be impermeable to air flow. These may be the rigid structural or finish materials used in the building envelope, such as glass or aluminum. However, if the structural materials allow air to flow through them, as does a concrete block wall for example, then additional impermeable materials must be incorporated in the building envelope to form the air barrier system.

While it can be readily accepted that the leakage of materials should be near to zero, it becomes increasingly difficult, if not impossible, to achieve zero leakage with more complex assemblies. This raises the question as to what test procedures can be used to determine the leakage rate of the assemblies being used in the building envelope and further, what leakage rate is acceptable for these assemblies.

Test Methods for Determining Air Leakage Rates

Materials

The tightness of an air barrier system depends on the use of impermeable materials. IRC has developed a test method to determine the air flow resistance of exterior membranes and sheathing[2], in response to a request from the CGSB committee on moisture control. A range of pressure differences are applied across a sample of the material and the air flow produced by the pressure difference is measured. From the data produced, a graph of air flow versus pressure difference is generated and the air flow rate at a given pressure can be calculated.

The procedure has been used to measure the air leakage of a number of common building materials, as shown in Table 1. Not unexpectedly, polyethylene shows 'no measurable leakage.' However, expanded polystyrene and fibreboard sheathing have a significant leakage. To put the leakage of the fibreboard in perspective, a 200 m² two-storey house sheathed in fibreboard, with no leakage at the joints, would have a higher leakage than permitted by the R-2000 program. The range of values for breather type building membranes is from tests on 15 different membranes available on the Canadian market.Though uncoated brick and concrete block walls are not strictly materials, these values are included for comparison purposes. Note that a number of materials, including the lower end of the building membranes, have very low leakage rates. These materials meet the criterion of near zero leakage for at least one material in the air barrier system. Since this list of materials is by no means complete, it can be assumed that other common building materials will also meet the requirement of very low, if not zero, leakage at 75 Pa pressure difference.

Table 1 Measured air leakage for selected building materials

Material	**Average leakage at 75 Pa L/s·m² surface**
0.15 mm (6 mil) polyethylene	no measurable

	leakage
25 mm expanded polystyrene	4.7
12 mm fibreboard sheathing	1.6
Breather type building membranes	0.011 - 3.6
Closed cell foam insulation	0.001
Uncoated brick wall	1.6
Uncoated concrete block	2.1

Assemblies

One of the easiest tests for the effectiveness of the air barrier system in assemblies is inspection. If you go on the building site after the air barrier is installed and can see through it, then you don't need an expert to tell you that it should be fixed. However, there are also a couple of test methods which will be helpful.

For testing of building assemblies, the American Society for Testing and Materials (ASTM) has two widely referenced standards on its books. The first, ASTM E283, is entitled "Standard Test Method for Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors."[3] This is a standard for laboratory measurement of air leakage through building assemblies and is commonly referenced in window and door standards. The second, ASTM E783, is entitled "Standard Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors."[4] As the title states, this is a standard for field measurement of air leakage and would be useful for field testing. Both of these standards are technically limited to windows and doors but the procedures can be used on opaque walls and roofs. Neither standard issued to determine structural integrity.

At IRC, we have been testing materials and composite wall sections in an apparatus which corresponds to ASTM E283. This apparatus can measure the air leakage of a sample 2.4 m^2 with a pressure difference of up to 2500 Pa. To run a test, a range of pressure differences are applied to the test panel and the corresponding air flow is measured. From the test data, a plot showing the leakage characteristic of the test panel is generated. These results allow the calculation of the air flow at the standard pressure difference of 75 Pa.

A series of tests on polyethylene membrane installed in a wood frame wall were run in this apparatus and the results written up as a Building Research Note.[5] Although polyethylene, as a material, showed no measurable leakage, an assembly of 4 mil poly with one 40 mm lap joint, did show a measurable leakage (Figure 5). As a matter of fact, after a pressure difference of approximately 100 Pa, the joint opened up and permitted more leakage. The point to be noted here is that it is not sufficient to include impermeable materials in the air barrier system; a leak free air barrier system results from having these materials joined with leak free joints.

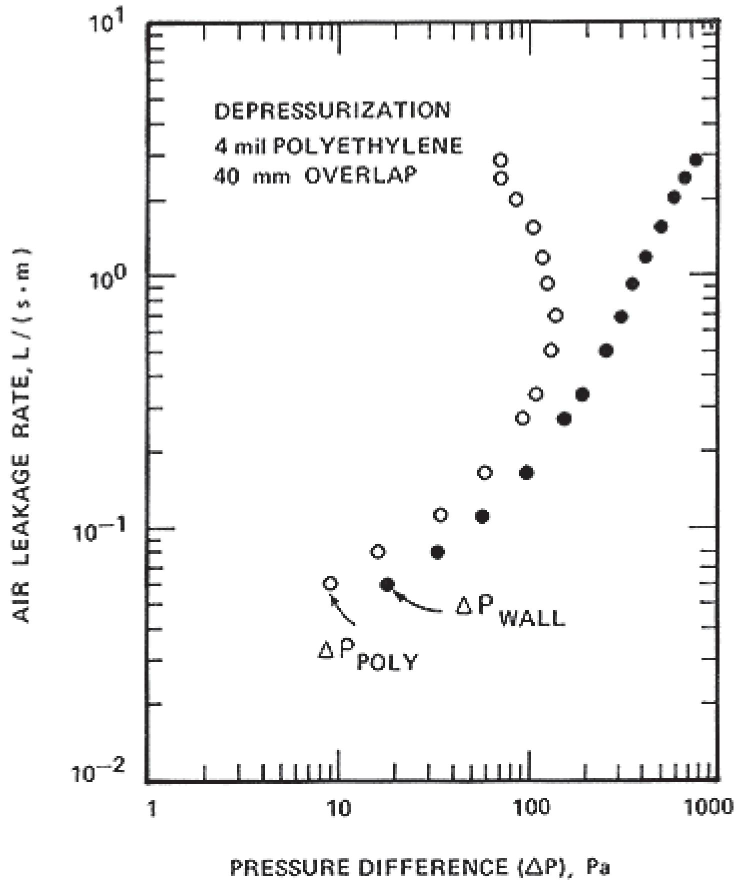


Figure 5 Decreasing ΔP across poly as wall ΔP increases; the joint in the poly is opening and its effectiveness as the 'plane of air tightness' is compromised.

Possible Leakage Acceptance Levels

The possibilities for buildings to leak and fail have existed throughout our history. And yet we can point to many buildings which perform their functions admirably and give rise to few, if any, maintenance problems. If these buildings also leak, why then do other buildings with similar air leakage rates have problems?

The amount of air flowing through the building envelope is influenced by many factors. Without pressure difference we have no flow and, as noted in the paper by Ganguli, pressure difference is generated by stack effect, mechanical systems and wind. The pressure difference will vary around the surface of the building and so the location on the building will also influence the amount of air flow. The type of air flow, as mentioned above, affects the rate of air flow. Finally, the dimensions of the leakage path, such as area, shape and length, will have a marked influence on the rate of air flow.

As we can see, the leakage of each air flow path is a consequence of a number of parameters. Calculation can determine what the air flow will be through a building if we know all the contributing factors and we calculate the flow through each opening, for each moment when the pressure changes. However, this alone does not indicate whether moisture will accumulate, or what the impact on temperature and energy consumption will be. And yet at some point before the onset of condensation or frosting, we will want to determine whether the chances for problems are high. Measurements of the leakiness of the air barrier system are the best indications we have at present for making such a judgment.

Most assembly standards which limit air leakage specify that the test should be conducted with an ASTM E283 apparatus. Table 2 shows permissible leakage at a standard test pressure of 75 Pa, as given in three standards.

Table 2 Standards on air leakage for various building assemblies

Standard	**Assembly**	**Permissible leakage at 75 Pa, L/s**
CAN3-A440-M84*	Windows - Openable	0.2-0.8 per m crack
Windows	- Fixed	0.07 per m perimeter
CGSB 82-GP-2M** Doors, glass, aluminum frame, sliding medium-duty	Doors- Patio	2.5 per m² surface
AAMA - Aluminum curtain wall design guide manual	Curtain wall Windows - Openable	0.3 per m² surface 0.8 per m crack

* Referenced in the National Building Code of Canada 1985 (fifth revisions, Jan. 1988).
** Referenced in Measures for Energy Conservation in New Buildings 1983.

The first is a CSA omnibus window standard,[6] which lists permissible leakage for openable and fixed windows. The range shown for openable windows is the extreme values for three rating levels contained in the standard, and represents an attempt by that committee to encourage the marketing of tighter windows. The second standard is the only door standard referenced by the "Measures for Energy Conservation in New Buildings."[7] It limits door leakage to

2.5 L/s per m² of surface area. The final standard is from the American Architectural Manufacturers Association (AAMA).[8] It limits leakage to 0.3 L/s per m² of surface area plus 0.8 L/s for each metre of openable window crack. The openable window values for the CSA and AAMA standards are identical. All of the permissible leakage values are based on a compromise between what can be built and what is required to limit energy cost.

AAMA allows an air flow of 0.3 L/s per m² of curtain wall section before it considers the wall section to be too leaky. The conditions which give rise to this number arise from the type of flow known as orifice flow, with climatic conditions we in Canada would consider fairly mild. Organizations and individuals within the building industry in Canada have recognized that the AAMA standard for allowable leakage should be reduced for general Canadian use. The conditions which we experience may involve long-channel flow and certainly a much more severe and lengthier winter season. The allowable leakage should be set at a level which will minimize problems due to moisture accumulation within the building envelope (this will also improve temperature control and reduce energy consumption). Thus the standard allowable leakage should also be based on the humidity within the building.

The International Centre for Research in Buildings (CIB) classifies humidity levels in buildings into three categories: low, medium and high. Low humidity, or Type 1, identifies buildings whose relative humidity is less than 27% at 21°C. Medium, or Type 2, is for relative humidities in the 27 to 55% range at 21°C; high, or Type 3, is for humidities in excess of 55% at 21°C. For Type 1 buildings, Canadian experience suggests that the allowable leakage rate should be set at half the AAMA standard for curtain walls or 0.15 L/s per m² of building envelope. Similarly, permissible leakage rates for Type 2 and Type 3 buildings would be set at 0.10 and 0.05 L/s per m².

At this time, these numbers are for discussion purposes only and are not recognized by IRC or any other organization. They are not part of any proposed standard. Of course they may be moved up or down as greater experience is gained in constructing buildings to tighter standards. We may find that the standards can be relaxed; or we may have to reduce leakage even further to reduce problems to a more manageable level. Either way we will have to proceed based on our experience and the best engineering and scientific knowledge available.

The leakage levels are meant for the acceptance of building envelope assemblies. They may not be easily applied to the testing of whole buildings; large localized leaks may still cause problems yet not cause the building to fail a whole building test. There is an additional need for commissioning tests and field investigation tools to determine where any remaining potential problems may start. Such tests may be based on the ASTM E783 or the CGSB standard, which is referenced by the R-2000 program.[9] Research laboratories and testing agencies have designed and built their own specialized tools and instruments and these are becoming standardized and available to the general construction industry.

Conclusion

A number of points can be made in conclusion.

First, we need an effective air barrier system designed into the building envelope. Not only is it required by the National Building Code, but an effective air barrier system will reduce or eliminate many of our building problems and failures.

Second, an effective air barrier system is one that uses impermeable materials joined into a structural plane of airtightness. This means that the joints between materials which make up assemblies are airtight, as are the joints between the various assemblies making up the air barrier system.

Third, we have the knowledge to develop techniques to determine the effectiveness of air barrier systems. The test procedures will involve the testing of materials, assemblies and systems. The acceptance criteria to be used with the test procedures, for the moment, will have to evolve from current standards. Experience will show whether these acceptance criteria are too tight or too loose.

Finally, air leakage through the air barrier system is only one of the concerns in the proper design of an effective air barrier system. Other factors, such as ultimate strength and durability, have to be considered in the overall specification and design.

References

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2. Bomberg, M. and M.K. Kumaran. A Test Method to Determine Air Flow Resistance of Exterior Membranes and Sheathing. Building Research Note No. 227, National Research Council, Ottawa, April 1985.

3. ASTM Standards, E283, Standard Test Method for Rate of Air Leakage Through Exterior Windows, Curtain Walls and Doors. ASTM, Philadelphia, 1986.

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5. Shaw, C.Y. Air Leakage Tests on Polyethylene Membrane Installed

in a Wood Frame Wall. Building Research Note No. 225, National Research Council, Ottawa, January 1985.

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7. Measures for Energy Conservation in New Buildings. NRCC 22432, National Research Council, Ottawa, 1983.

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9. CGSB Standard CAN/CGSB-149.10-M-86, Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method. Canadian General Standards Board, Ottawa, 1986.

This article was published as part of the technical documentation produced for Building Science Insight '86, "An Air Barrier for the Building Envelope," a series of seminars presented in major cities across Canada in 1986.